Alberta ENERGY

Scientific and Engineering Services

Advanced Coal Mining Techniques for Alberta

Projects supported in part by the Alberta/Canada Energy Resources Research Fund

ALBERTA OFFICE OF COAL RESEARCH & TECHNOLOGY

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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal and conventional energy resources, as well as energy conservation and renewable energy. Program administration is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In recognition of the importance of coal to Alberta's economy, the Alberta Office of Coal Research and Technology was established in 1984 within Alberta Energy and Natural Resources (now Alberta Energy). Its primary purpose is to encourage the development and application of new technologies related to Alberta coals. The Office provides funding contributions to research and development projects in industry, academic institutions and other research establishments and monitors their progress in an overall program of improving the production, transportation and marketability of Alberta coals.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page 10.

Advanced Coal Mining Techniques for Alberta

In 1977, the Coal Mining Research Centre (CMRC) (now Coal Mining Research Company) was established in Edmonton with funds provided by the Alberta/Canada Energy Resources Research Fund (A/CERRF). At the time, it was understood that A/CERRF funds would be used to help establish CMRC, but that the long-term objective of CMRC was to generate an increasing level of financial support from the private sector. To some considerable extent, this has since been accomplished.

The mandate of CMRC is to conduct applied research to improve coal mining and preparation by:

- increasing efficiency, safety, economy and recovery in mining and preparation operations; and
- improving the working environment of the labour force.

During the intervening years from 1977 to the present (1989), CMRC staff conducted several research projects on behalf of A/CERRF (as well as others for industry) aimed at introducing new or advanced coal mining technologies to Alberta's coal industry. Those projects supported by A/CERRF are described here.

Within CMRC's mining technology program, three priority research areas were identified:

- exploration, with initial emphasis on geophysical borehole logging techniques (described in another technology transfer publication in this series);
- surface mining and reclamation; and
- underground mining.

Surface Mining and Reclamation

Subbituminous coals are the most abundant of all coal types found in Alberta. In 1987, they represented 64 per cent of Alberta's total coal production. Because of their importance to Alberta's coal industry and the fact that they are surface-mined, several surface-mining projects were begun in 1981 on the basis of two factors:

- in the future, recovery of coal from greater depths will be necessary. This will require removal of thicker layers of overburden; and
- the introduction of more stringent soil reclamation requirements, particularly in areas where sodic (high sodium content) soils occur, will demand selective mining and replacement of overburden after mining operations have ceased.

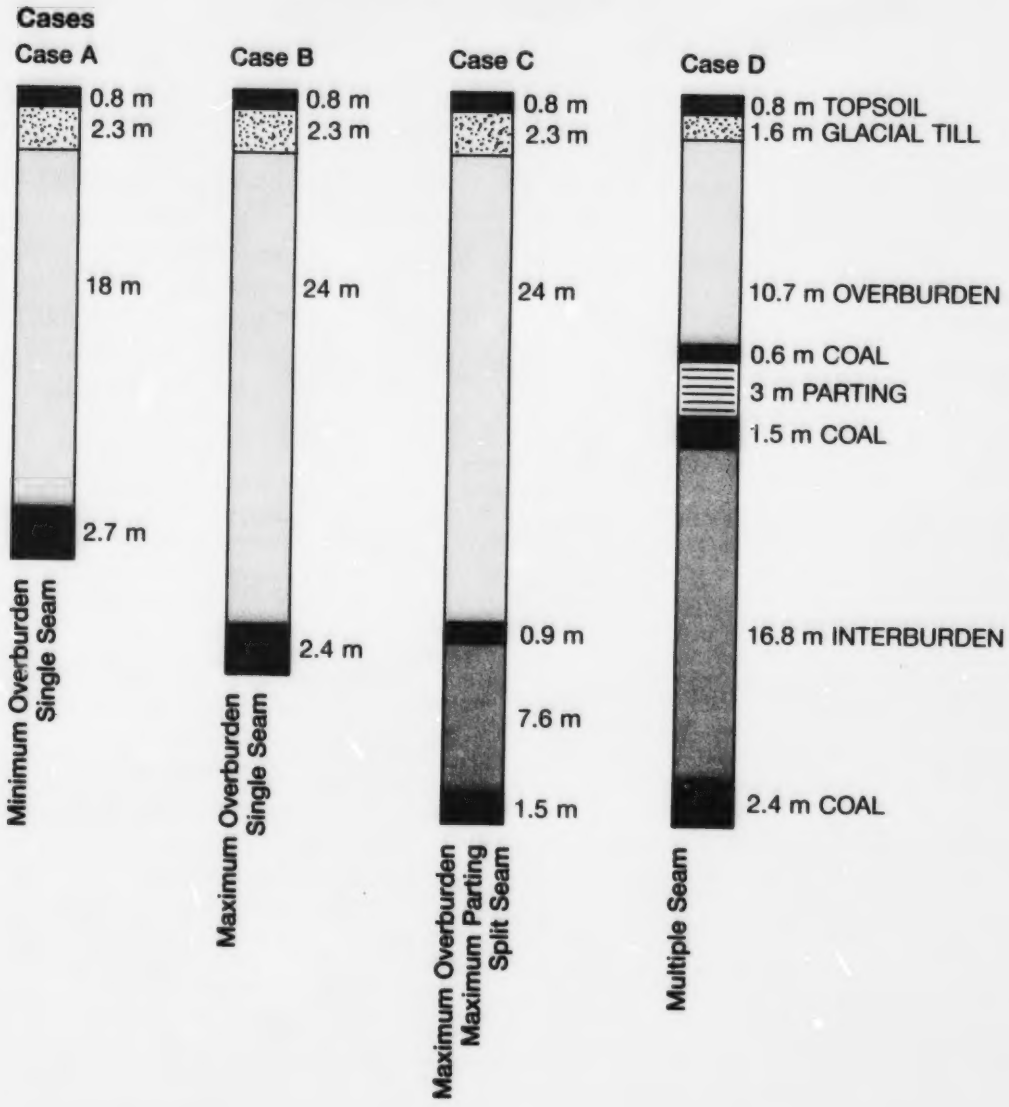
Comparative Evaluation of Cross-Pit Conveyor Systems

A detailed economic and technical evaluation was made of five mining schemes in which the primary soil stripping unit, a dragline, was complemented by an auxiliary system for placement of the upper horizons of strata as an aid to reclamation. A production level of 1.5 million tonnes a year was assumed, along with the requirement that three layers of overburden must be handled and placed separately in the order existing before mining occurred. Also, certain lithologic profiles were assumed.

The five schemes were:

- a single dragline for overburden removal, plus scrapers to handle topsoil and glacial till. This represents current coal mining practice;
- a single dragline used for direct casting of overburden, with a bucket wheel excavator/ cross-pit conveyor (BWE/CPC) for removal of topsoil, glacial till and a portion of the overburden;
- a single dragline for overburden removal, with hydraulic shovels and trucks for handling topsoil and glacial till;
- a single dragline or multiple draglines for overburden removal, with hydraulic shovels and trucks for handling topsoil and glacial till; and
- all materials handled by shovels and trucks.

Lithological Sections Considered in the Evaluation of Cross-Pit Conveyor Systems



(Source: *Progress in the Mining Technology Research Program of The Coal Mining Research Centre, Alberta.* Barron, K. CMRC Report 82/16-T, March 1982)

Comparative Economic Evaluation of Cross-Pit Conveyor Systems

Lithologic Case	Base System		BWE/Cross-Pit Dragline System		Modified Base System		Min. Cost Dragline/Shovel System		Shovel/Truck System	
	Total* $\$ \times 10^6$	Cost/ Tonne $	Total* $\$ \times 10^6$	Cost/ Tonne $	Total* $\$ \times 10^6$	Cost/ Tonne $	Total* $\$ \times 10^6$	Cost/ Tonne $	Total* $\$ \times 10^6$	Cost/ Tonne $
A	7.4	4.93	6.2	4.14	6.5	4.33	6.5	4.33	6.9	4.60
B	9.1	6.07	6.8	4.53	8.1	5.40	8.1	5.40	11.6	7.73
C	11.5	7.67	9.1	6.07	10.5	7.00	9.2	6.13	13.7	9.13
D	7.5	5.00	5.8	3.87	7.1	4.73	6.7	4.47	6.9	4.60

* $/year – ownership and operating costs (1980 Canadian dollars).

(Source: *Progress in the Mining Technology Research Program of The Coal Mining Research Centre, Alberta.* Barron, K. CMRC Report 82/16-T, March 1982)

At the time of this comparison (all costs were reported in 1980 dollars), it was found that the lowest cost scheme for selectively mining and placing the three designated soil horizons involved the use of a dragline supplemented by a BWE/CPC. It was noted, however, that the results are site specific and little is known about the performance of BWEs under Alberta operating conditions.

Reclamation in the Ardley Coal Zone

The Ardley coal zone is one of the most important sources of subbituminous coals in Alberta, but sodic soils are common in many areas. This complicates mine reclamation efforts because soils removed during mining must be replaced in a specified order before the land can be returned to agricultural use. Also, certain chemical treatments will likely be required to minimize the effects of the high sodium content soils on plant growth. Consequently, reconstruction of soil profiles following coal mining has been one focus of an extensive soil reclamation research program jointly managed and funded by the Alberta government and Alberta's coal industry. CMRC contributed to this program by evaluating the costs of various alternative methods for separate placement of the upper 3 m of overburden. These evaluations were based on production of two million tonnes a year of coal from a 2.7-m thick seam under 17 m of overburden.

Of the seven alternatives considered in this evaluation, the least expensive involved the use of a bucket wheel excavator and a cross-pit conveyor. The most expensive combination of equipment involved a dragline, loader and truck.

Associated with this reclamation work, CMRC participated in a mine-dewatering project at the Whitewood Mine from 1979 to 1982. It resulted in a more stable highwall, a steeper highwall angle and greater productivity from the pit.

Diagnostic Maintenance

During an 18-month field trial, infra-red monitoring and vibration analysis techniques were used as diagnostic maintenance tools to monitor components of draglines, shovels and other surface-mining equipment. The objective was to determine the suitability of these instruments in predicting imminent equipment failure. This would allow equipment operators to avoid some unscheduled downtime.

It was found that infra-red monitoring was not satisfactory, but vibration analysis was useful as long as baseline conditions had been established on properly operating equipment.

Cost Analysis ($/hectare)*
Mining and Selective Handling
17 m Total Overburden Depth

Depth Selectively Handled (m)	** Dragline only	DL/Scraper/Dozer	DL/Loader/Truck	DL/Shovel/Truck	DL/BWE/Truck	**BWE/Round-Pit Conveyor	**BWE/Cross-Pit Conveyor
0	121 800	121 800	121 800	121 800	121 800	147 600	118 500
1	–	134 100	136 300	130 700	129 200	147 600	118 500
2	–	146 000	150 400	139 300	138 800	147 600	118 500
3	–	158 000	164 700	147 900	143 200	147 600	118 500

* Costs are in Canadian $/ha for ownership and operating expenses

** The dragline has the capability of excavating up to 22 m of overburden whereas the BWE/conveyor systems selected have the capability of excavating to only 18 m.

(Source: *Progress in the Mining Technology Research Program of The Coal Mining Research Centre, Alberta.*
Barron, K. CMRC Report 82/16-T, March 1982)

During 1981/82, two University of Calgary professors (G. Walker and A. Doige), in co-operation with CMRC, developed an analytical model that simulates the dynamic characteristics of the braking and steering systems of a loaded mine truck descending a grade with banked curves. The study showed that continued growth in the payload (up to 1000 tonnes) of mine trucks demands a critical review of the procedures for truck design. It recommended that a philosophy other than building new trucks "the same but bigger" was required.

Also associated with surface mining was a 1984 study that resulted in the development of a computer program to estimate the bulldozer production rates for waste dump resloping. Calculations are based on standard performance curves and common operating procedures for bulldozers. CMRC should be contacted regarding use of the program.

Underground Mining

Although underground mining is uncommon in western Canada, and is used at only one coal mine in Alberta (along with surface mining), it is expected that more underground mining will be required in the future, including mining operations in the Alberta plains. This will likely be accomplished with longwall retreat methods of mining, with some use of shortwall techniques and some room-and-pillar mining in specific situations involving faulted seams. In the mountains and foothills, where mining conditions are more complex than on the plains, no single mining technique is expected to predominate. Therefore, two requirements common to all mining regions of Alberta were identified:

- determination of entry drivage rates and costs; and
- the use of proven longwall mining technology in a wide range of conditions and with high rates of productivity.

To provide a method for assessing the economic potential of these various mining procedures, computer programs were developed to evaluate mine productivity and costs. One program evaluates these factors for in-seam entry drivage systems with up to five entries. It uses alternative support methods combined with either shuttle car or continuous haulage for coal clearance from behind the continuous miner. A second program can be used to evaluate the production potential of longwall mining systems. A third computer program was developed to analyse the stability of pillars in coal mines.

Mining Subsidence Handbook

In the early 1980s, available information for predicting mining subsidence in the Lethbridge area of Alberta was reviewed. Following release of the report of this investigation, mining engineers pointed out their need for a handbook which described methods of predicting, measuring and controlling subsidence under western Canadian operating conditions. Subsequently, in 1985, a publication was produced in response to that need. The 223-page book, entitled *Measurement and Control of Mining Subsidence*, is available from CMRC and includes case histories from the United Kingdom, the United States and Australia.

Coal Mining in 2035

The nature of coal mining in Alberta, and production technologies likely to be used by the industry from 1986 to 2035, were predicted in a three-volume report prepared in January 1986.

In this study, the current status of Alberta's coal reserves was reviewed. The best available information regarding production forecasts was consulted to make some predictions about the future growth of Alberta's coal business. Also, current and emerging mining technologies were reviewed for both surface and underground mining. This information, along with an appreciation of the conditions under which coal is mined in Alberta, was used to draw the following conclusions about coal mining in 2035:

- to meet future demands, coal production is expected to exceed 80 million tonnes a year in 2010, and be approximately 200 million tonnes a year in 2035. This assumes that coal will continue to be used as the primary fuel for electricity generation, and continued growth will be experienced in international and Canadian demand for bituminous thermal coal;
- strip ratios and overburden thicknesses will increase over the next 50 years, but mining conditions will likely be similar to those in 1986;
- surface mining will continue to be the principal coal mining method in Alberta for the next 25 years at least, although underground mining will be considered where appropriate. After 2010, an increase in underground mining is likely;
- a review of current and emerging technologies shows that some developments and techniques, which are already available and appropriate for Alberta, have not been adopted by the coal industry; and
- mining techniques are not likely to change substantially over the next 25 years. However, innovations such as automation, remote control and the widespread use of sensors and computer-based techniques will contribute to the efficiency, productivity and safety of all aspects of coal mining.

Based on the information in this report, the Mining Division of CMRC developed the Innovative Mining Technology Program. It identifies the challenges to be met and provides a focus for future research. Three projects which evolved from this program and were partially funded by A/CERRF are described below.

Meanwhile, in February 1987, a workshop was held at the Coal Research Centre, Devon, which used the "2035 Report" to initiate discussions about advanced mining technologies known to be emerging world-wide. Approximately 60 people attended the workshop. They represented mining companies, equipment suppliers, electricity producers, consultants, advanced technology companies, governments and universities. Papers presented by the research community and equipment suppliers emphasized research opportunities offered by automation, monitoring equipment, laser applications and advanced telecommunications techniques. Proceedings of the workshop are available from CMRC.

Automation and Robotics in Coal Mining

In 1987, CMRC researchers undertook a review of existing automation technology. They also held discussions with operators of some Alberta and British Columbia coal mines to determine their priorities with respect to mining operations that could, or should, be automated. From this investigation, two additional studies were commissioned by A/CERRF and administered by the Alberta Office of Coal Research and Technology. They concerned non-cable vehicle guidance systems and the use of lasers in coal mining.

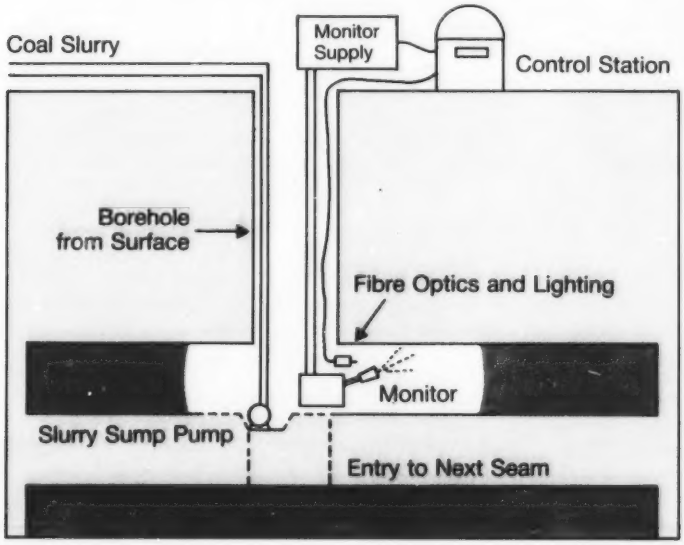
Non-Cable Vehicle Guidance

The history of industrial development is rife with examples of automation having been adopted wherever technical and economic benefits could be realized. One of the more recent subjects of automation research is the development of automated vehicle guidance systems. Although some work has been done on guidance systems for equipment used in underground mining, little has been done to develop automated vehicles and equipment for surface mining.

Consequently, since surface mining is expected to predominate in Alberta for several decades, and the competitive nature of the coal industry encourages investigation of every opportunity to reduce mining costs, a detailed review was made of non-cable vehicle guidance systems that might be used in Alberta's coal industry. Such devices might help lower mining costs and reduce safety concerns, but they could also represent an opportunity to manufacture new products and diversify Alberta's economy.

Some of the technologies reviewed included systems based on inertial guidance, dead reckoning, radar, laser beacons, ultrasonics, machine vision and radio frequencies. It was concluded that technologies having the greatest potential for use in Alberta coal mines should employ radar, ultrasonics, lasers, dead reckoning and guidance algorithms.

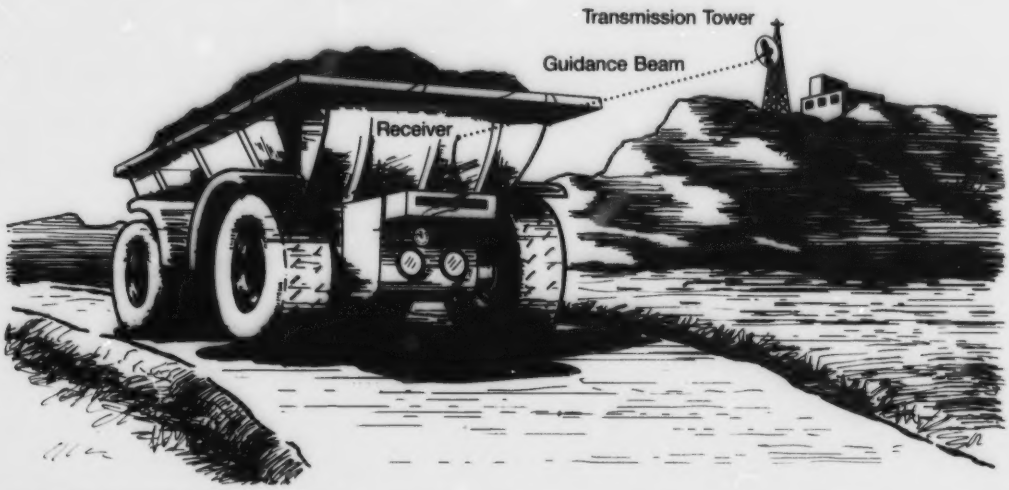
The most promising systems were investigated in terms of range, accuracy, flexibility, reliability and costs. It was recommended that two devices should be developed and tested under local mining conditions. The first, an improved dragline monitor, was suggested because no suitable device exists to monitor dragline performance, even though a reduction of only a few seconds in the load-swing-dump cycle of a dragline could result in millions of dollars in savings in a year.



Looking ahead to the 21st century, it is possible that underground mining in Alberta will be performed by equipment that is remotely controlled from the surface.

(Source: Coal Mining Research Company)

Remote Guidance System for Mobile Haulers



(Source: *Coal Mining in Alberta 1986-2035, Volume III.* Coal Mining Research Company Report 8519-D3, 1986)

The second device, which the coal mining industry and the Coal Mining Research Company believed should be developed, is an automated machine control system for selectively mining coal adjacent to partings and waste material. This device, called an Automated Machine Control for Optimized Mining (AMCOM), is to help reduce the amount of coal lost and the amount of foreign material introduced when mining occurs at coal/waste interfaces.

Lasers in Coal Mining

As with most industries today, many day-to-day aspects of coal mining lend themselves to laser technology, but thus far lasers have been used only for land surveys and equipment positioning.

In this study, a review was made of potential laser applications, with specific reference to potential uses in coal mining. Included in the survey were discussions with laser researchers. The report concluded that available laser technology can be used in coal-mining environments for welding, surface treating, guidance, stability monitoring, data transmission and voice communication. The greatest potential is in equipment monitoring and control to improve the productivity of materials handling. The final reports for both of these automation projects provide an excellent review of current technology.

Subsequent Developments

In 1987/88, more than 50 per cent of the revenue earned by CMRC was derived from industry-supported research and development. This support by industry is interpreted to mean that initial investments by A/CERRF have aided Alberta's coal industry and coal research community. Since those initial investments, CMRC has evolved into an independent, private, non-profit company. It expects to derive approximately 83 per cent of its revenue in 1988/89 from contracts for research and development (R&D) services in direct response to the needs of government and the coal industry. The remainder will come from an agreement between CMRC and the Alberta Office of Coal Research and Technology which provides for the initial developmental stages of the AMCOM system and a dragline monitor.

Since the benefits of this type of R&D accrue to the individual coal companies rather than to CMRC, it is difficult to measure the monetary value of such research. However, the increasing amount of revenue from industry contracts, and the increasing proportion of CMRC's total revenue which this represents, would seem to indicate that the coal industry is realizing value from the services provided by CMRC.

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Other publications in this series which are available and deal with coal research include:

An Economic Analysis of Coal Pipeline Systems, 6 pages, January 1987.

Opportunities to Use Coal in Enhanced Oil Recovery, 8 pages, April 1988.

Development of an Agglomeration Process to Beneficiate and Transport Alberta Coals, 14 pages, June 1988.

Gasification of Western Canadian Coals, 14 pages, June 1988.

Coal Research Centre, Devon, 10 pages, August 1988.

Co-processing Studies of Alberta Subbituminous Coals, 14 pages, December 1988.

Mathematical Modelling of Automedium Cyclones, 10 pages, January 1989.

The Technical Committee Approach to Coal Research, 6 pages, January 1989.